Interim Report

DST Project
on
Finger Printing of South Indian Panchaloha Idols

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Government Museum, Chennai

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X- and gamma radiography of 9th - 13th century South Indian Icons

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Introduction

As part of the second campaign of the DST Project on Fingerprinting of Ancient South Indian Bronzes, 50 icons belonging to the Pallava, Chola and Vijayanagara period were radiographed at the Government Museum Chennai. The physical principles of radiography, the radiographic setup, etc. have been detailed in the report of the first campaign. A brief description about the physical features of some of the investigated icons is given in Table - I. The photographs of some of the icons are given in Figure 1.

Experimental setup

The experimental setup used in this campaign was also similar to the first one. The X-ray equipment used in this campaign was the Eresco 200 MF unit of M/s Siefert, Germany. This is an air cooled unit most suited for field applications. The technical details of this unit and the typical radiographic parameters employed are given in Table - II. Apart from X-rays, gamma rays were also used as the source. A tech-ops 660 camera with an Iridium source having an activity of about 13 Ci was also used. Adequate safety precautions were taken during the entire radiographic campaign such as cordoning off the area and putting suitable stickers and indicators. The improvements in the present campaign over the first campaign include

1. Variety of icons - while the first campaign concentrated on small icons, in this campaign a mix of small medium and large icons were investigated. The size of the icons investigated ranged from 15 mm to about 4 feet.

2. Apart from X-rays, gamma ray source Ir 192 was also used for radiography to cover the thicker portions of the icons while X-rays were used to cover the thinner regions. Under the given conditions of geometry, a sensitivity level of 2 % could be achieved.

3. Variation in technique - Panoramic exposure was adopted thus effectively utilising the source and reducing the overall exposure time.

4. Use of multi film technique to cover greater thickness variations in the

icon was also adopted which also decreased the overall time of exposure for each icon.

Observations

The summary of observations made during this campaign is outlined below.

1. Defects if any in an icon were mainly porosities and cavities.

2. As observed earlier, the main body of icon was practically of very good quality. However, the base (pedestal region) and other structures such as the *prabhavalli* were not of the same quality.

3. In practically all the bigger icons, it has been observed by radiography that the main body of the deity, the pedestal and associated features like *Prabhavali (S)* etc. were cast independently and were subsequently forge welded. Joints between the body and the pedestal were revealed in the radiographs. It was observed that reference studs were used to facilitate the alignment of the red hot individual parts of the icon during forge welding.

4. In general a comparison of the icons indicate that smaller size icons have practically very few number of defects while the large ones have a number of defects.

5. In the large ones in case the complexity of the icon increases (such as Nataraja) a large number of porosities and cavities are observed. Figure 2 reveals the voids and cavities detected in the leg of a 13th century Nataraja.

Table-I
Physical description of some of the investigated Icons

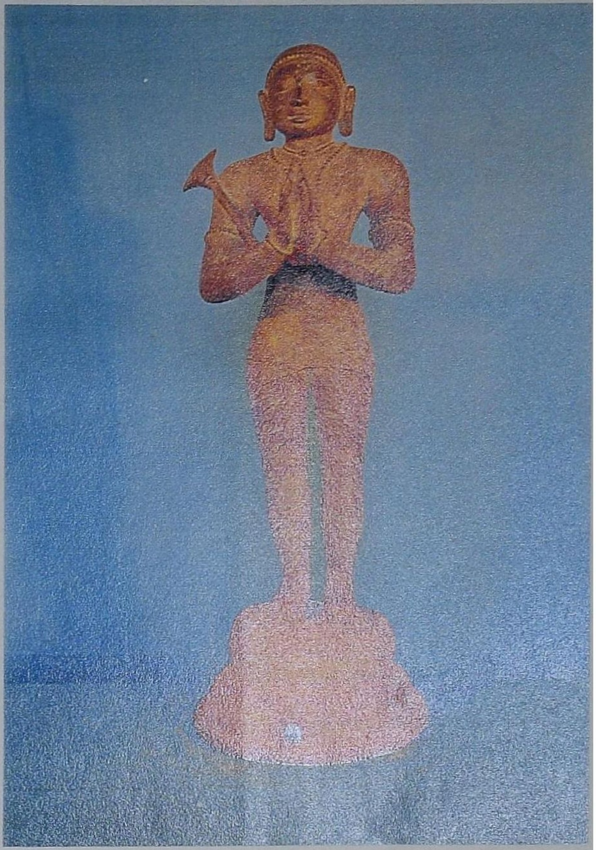
ICON	ACC.NO	PLACE OF EXCAVATION	PHYSICAL DESCRIPTION
GANESA	1761/94	Pavattakkudi Nagapattinam District	Standing on a oval padmasana over a rather square bhadrasana which has two spikes. Short karanda makuta present over the head. Ankusa, pasa, broken tusk and sweetmeat in the hands, short legs.
UMASAHITA	601/67	Tirivelichipatti, Trichi district.	Siva and Parvati standing in elegance. In between them is small cochant Nandi. Siva holds an axe and antelobe in the upper hand. Parvati is two armed right is abhaya and left one is lola.
VISHNU	625/68	Siddhavazuvur, Thanjavur District. .	Standing erect on a circular disc, meant for soldering on a pitha. The upper right hand holds a chakra and left carries a sankra both has flames. The lower right hand is in abhaya; while the left placed over a lengthy mace. The kirita is conical. The under garment has wavy pattern, udharabandha, sacred thread, siraschakra are present.
APPAR	343	Vembavur, Trichy Dist	Height : 57 cm. : Hair close to head. Hands in anjali pose, spud leaning against right shoulder. Upper necklace and wristlets each a simple band with large clasp; lower necklace hanging between breasts, composed of rudraksha beads as are also the chaplet on the head and a string round the upper part of each arm. Short cloth round loins.

TABLE - II

RADIOGRAPHIC PARAMETERS

EQUIPMENT	
X-ray	: Eresco 200 MF of M/s Siefert, Germany with a voltage range of 10 - 200 kV
COOLING	: Air cooled
GAMMA RAY	: Tech-Ops 660 of M/s Amersham, with a IR - 192 source of strength 13.6 Ci
FOCAL SPOT	: 1.5 mm for X-ray and 3.0 mm for gamma ray
VOLTAGE RANGE	: 100 - 160 kV
FILM USED	: Agfa D2 fine grain slow speed, Fuji 80 medium speed and Kodak AA400 fast film
SCREENS USED	: Front Pb screen 0.1 mm thick and Back Pb Screen 0.15 mm thick
PROCESSING	: Manual, Standard (Developing time depends on bath temperature)

GANESA
Acc.No:1761/94



APPAR
Acc No: 343

UMASAHITA
Acc.No: 601/67

CHANDIKESHVARA
Acc No: 330

RAMA
Acc No: 786/75

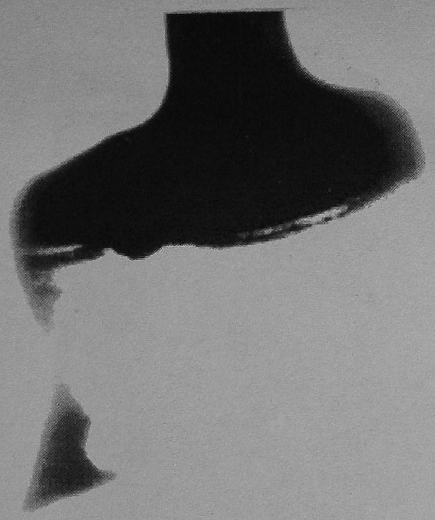
MAHISHASURAMARDINI
Acc No:247/53

Fig.2 Voids and cavities in the leg of 13 th century Nataraja-Positive print of radiograph

VISHNU

Acc.No	:	642/69
Location	:	Government Museum, Chenai
Place of Excavation	:	Mangalam, Salem District

Physical Description : Seated on a padmasana over an inverted padma: the left hand is broken. Right one has discus. The lower right holds something while lower left holds a gada in horizantal position. Wears the usal sacred thread,necklases etc. the position of srivasta is noteworthy. The right leg hangs down, while the left leg is resting on the pedestral. Wears padasaras. The hanging right leg is supported by a pedestal.



Radiographic Observation:

Parameters	
Source of Radiation & Energy	X-rays, 140 kV
Focal Spot	1.5 mm
Exposure	30 mA-mts
Source to film distance	700 mm
Type of film	D2, Fuji NPIX-80,Kodak
Processing Conditions	Manual
Typical defects Observed	
Gap in the pedastal marked	

Microstructure- Observation

Cast microstructure similar to leaded red brass. Multi phase structure with segregation (coring). Lead particles are unifromly distributed and a few shinkage cavities are also noticed.

HANUMAN

Acc.No : 161

Location : Government Museum, Chenai

Place excavation : Vadakkupanaiyur, Thanjavur District.

Physical Description : The devotion for man of his animal servant, friend is wonderfully depicted in this simple but expressive image. There is chaplet of leaves on the head, pendants adorn the ears, the sacread thread is broad and undivided, a wristband is present and the loin cloth is decorated with pattern suggesting Vishnu's discus.

Radiographic Observation:

Parameters	
Source of Radiation & Energy	Ir-192
Focal Spot	3 mm
Exposure	300 curie-mts
Source to film distance	700 mm
Type of film	D2, Fuji NPIX-80, Kodak AA
Processing Conditions	Manual
Typical defects Observed	
Cavities in the fore arm	

Microstructure- Observation

cast microstructure similar to leaded tin bronze.

DST Project
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MICROSTRUCTURAL INVESTIGATIONS OF 9TH-13TH CENTURY PALLAVA AND CHOLA IDOLS

Division for PIE & NDT Development
Indira Gandhi Centre for Atomic Research, Kalpakkam
Government Museum, Chennai

In-Situ Metallography of South Indian Idols belonging to 9th - 13th Century Pallava and Chola period

Any metallic specimen will carry its metallurgical history through its microstructure. Thus, evaluation of the microstructure gives information not only on the current nature of the specimen but also sometimes on the past history of the specimen. The south Indian Panchaloha idols are made by a technique called *'lost wax'* process. In this process, a wax model of the idol is prepared with all its intricate details. This wax model is coated with fine clay and a clay model is prepared. Molten metal is poured into this mould. The hot metal melts the wax and replaces it as it flows into the mould. Hence the name *'lost wax process'*. Suitable runners and risers are incorporated in the wax model to allow free flow of molten metal. The risers are designed to take into account the shrinkage of the metal during solidification and subsequent cooling. The moulds are allowed to cool and the mould is broken to take out the idol. The runners and risers are cut off and the finishing touches are given to the idol. Thus it can be seen that the Panchaloha idols reveal essentially cast structure. In general, the idol, the pedestal and the prabhavali are cast separately Joining them together requires hot forging. The metallurgical treatment given to Panchaloha will leave its characteristic imprint on the microstructure of the idol. Thus, the microstructure of a particular region of the idol would form one of the characteristics of the fingerprint of that idol.

Since the history of most of the idols is not recorded, there is no specific information about the ore or the parent metal and alloying additives employed. Also, it is not known whether the additives are added with specific knowledge of their influence on the castability, workability and the strength of the idol. It is also possible that these additives might be present in the prevalent metal, depending on where from the ore was obtained. Thus these additives can also be unintentional. Metallography along with other investigations like chemical analysis, would reveal the metallurgical history of the material and throw light on the above possibilities.

In general, for conventional metallography, a representative specimen is cut from the material, to a suitable size. The cut specimen is moulded in araldite. The whole mould is polished to an optical finish. The microstructure is revealed by suitable etching process. The specimen is then put under optical microscope and the microstructure is observed. Obviously this procedure, if followed, involves removal of a part of the idol which is not desirable. Therefore, a modified metallographic technique called in-situ metallography was adopted in this campaign.

Replica technique was employed for in-situ metallography. Standardized procedure was developed for polishing and etching and then taking the replica. A variable speed, portable grinder head, with suitable modifications to change the abrasive sheets is used for polishing. Abrasive sheets are changed starting with 100 grit size (coarse) to 600 grit size (very fine) gradually. Finally, the region is polished with a diamond paste of one micron size to get an optical finish. The orientation of the grinding is changed with every change of abrasive sheet to ensure uniform polishing. The region is then thoroughly cleaned with analar grade acetone and dried. Chemical etching using alcoholic ferric chloride solution (30ml HCL, 10 ml $FeCl_3$ and 120ml methanol) has been employed for revealing the microstructure. A clean cellulose acetate tape softened with analar grade acetone is then pressed onto the surface of the polished region. It is evenly pressed, so that the softened tape takes the shape of the contours of the microstructure. After a few minutes, the tape is peeled off. Such a replica was also taken before etching to reveal the porosity, interdendritic cavities and microcracking, if any.

OBSERVATIONS

Insitu metallography was carried out on eighteen idols. Metallography was done on incospicuous regions, mostly on the underside of pedastal. Some microstructures were taken on the base / foot region of the idol if there is no pedastal. Metallography was not done on some idols where suitable inconspicuous region could not be found. Detailed observations on the microstructural features for each of the idols are listed in Table-I.

MICROSTRUCTURAL INVESTIGATIONS ON ANCIENT IDOLS

TABLE-I

S. No.	Accn. No.	Name of the Idol	Region of Mettalography	Observations
1.	247/57	Mahishasuramardini	Inside of the Pedestal	Cast microstructure similar to Leaded Tin bronze Dendrites show segregation. Lead particles (black dots) are uniformly distributed.
2.	601/67	Umasahita	-do-	Sand cast microstructure similar to Leaded red brass with shrinkage cavities (black interdendritic network along grain boundaries)
3.	625/68	Vishnu	-do-	Sand cast microstructure similar to Leaded red brass. Particles of lead (black dots) and shrinkage cavities (black network) along grain boundaries
4.	642/69	Vishnu	-do-	Cast microstructure similar to Leaded red brass. Dendrites with segregation (coring) Lead particles are uniformly distributed and a few shrinkage cavities are also noticed

Based on the microstructural analysis, the idols are classified into two groups.

I. Leaded Tin bronze ---> 247/57, 1341/86, 1436/88, 1709/90, 1761/94, 1782/94, 1885/96.

II. Leaded red brass ---> 601/67, 625/68, 642/69, 673/71, 1345/86.

Based on the cavities present in the microstructure, the idols are classified into three groups.

I. Minimum interdendritic cavities ---> 247/57, 1341/86, 1436/88, 1709/90., 1885/96.

II. Intermediate interdendritic cavities ---> 601/67, 673/71, 1782/94.

III. Maximum interdendritic cavities ---> 625/68, 642/69, 1345/86, 1761/94.

All the idols with microstructure similar to Leaded red brass have shown the tendency for higher shrinkage cavities. Idols having microstructures similar to Leaded Tin bronze are generally found to be of better quality with less shrinkage cavities

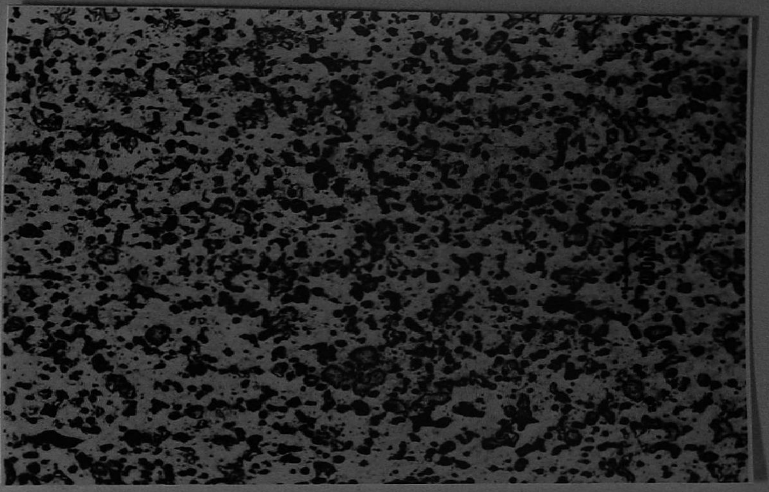

Fig. 1 Microstructure of the idol No. 247/57

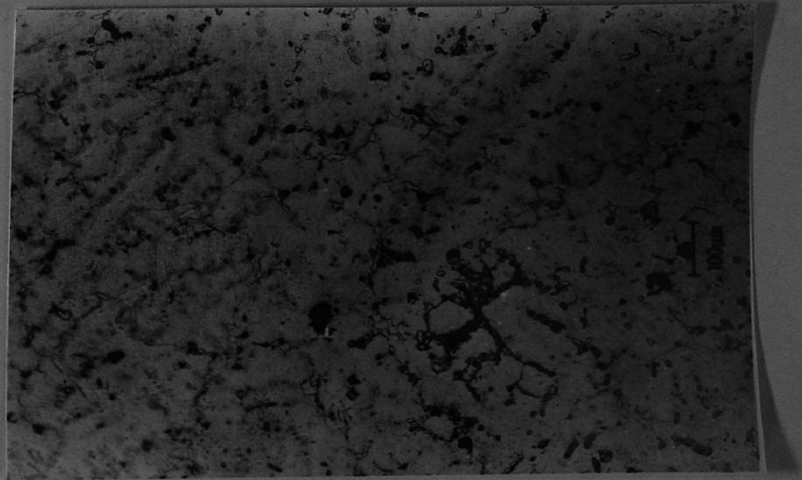

Fig. 2 Microstructure of the idol No. 601/67

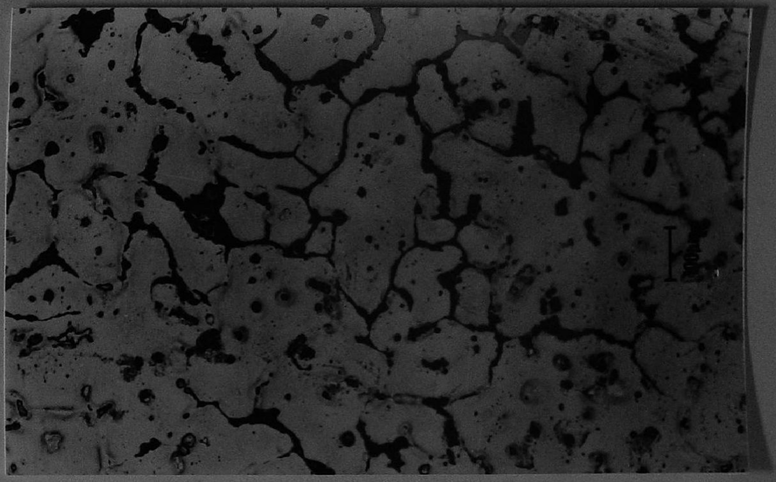

Fig. 3 Microstructure of the idol No. 625/68

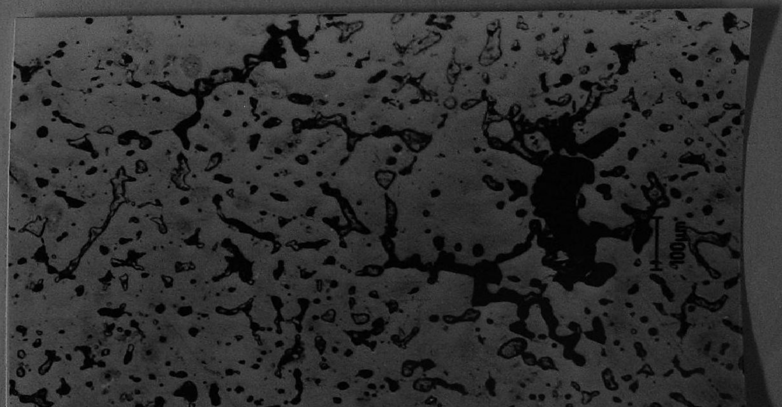

Fig. 4 Microstructure of the idol No. 642/69

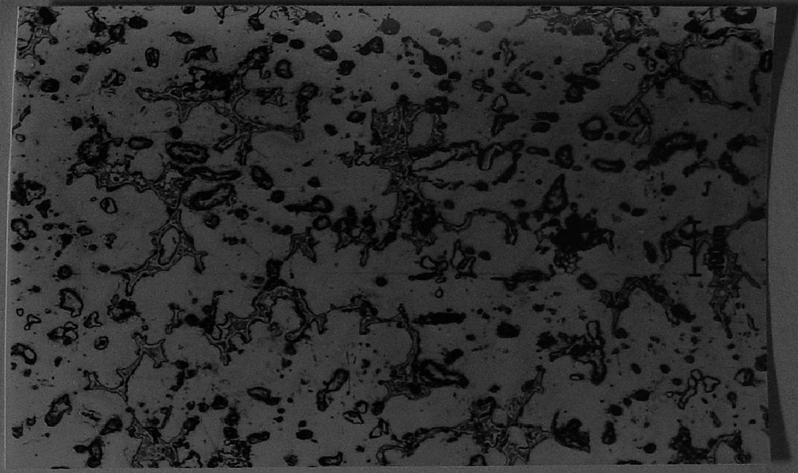

Fig. 5 Microstructure of the idol No. 673/71

Fig. 6 Microstructure of the idol No. 1341/86

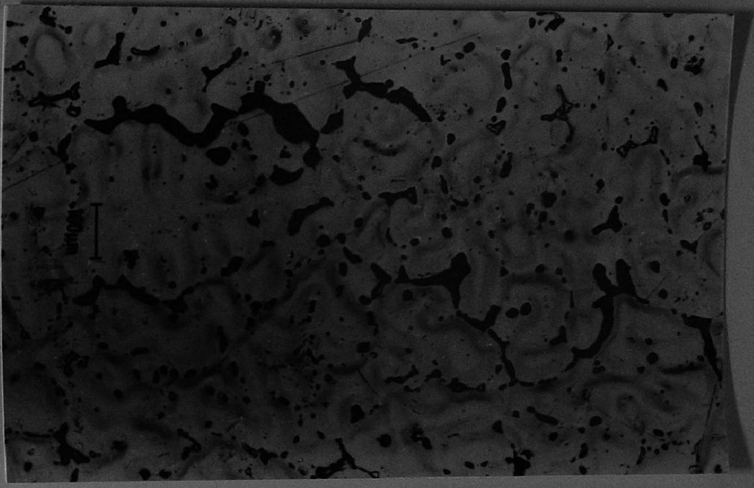

Fig. 7 Microstructure of the idol No. 1345/88

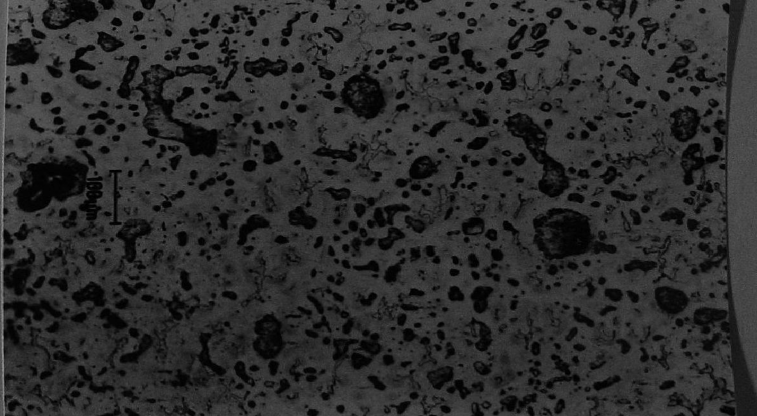

Fig. 8 Microstructure of the idol No. 1436/88

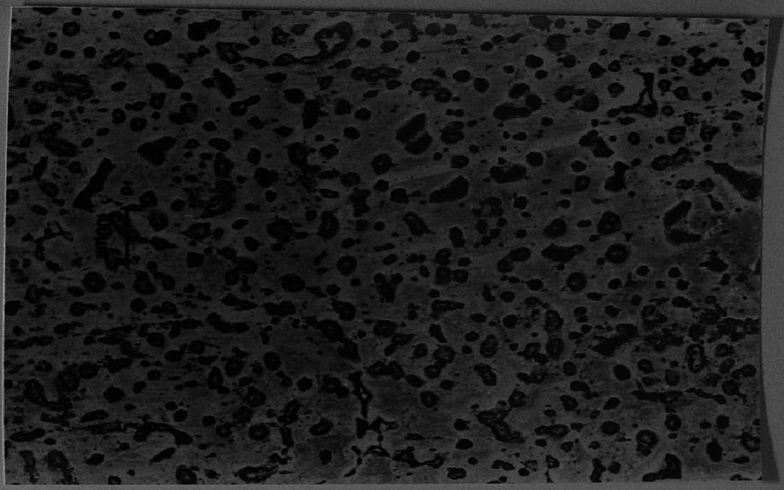

Fig. 9 Microstructure of the idol No. 1709/90

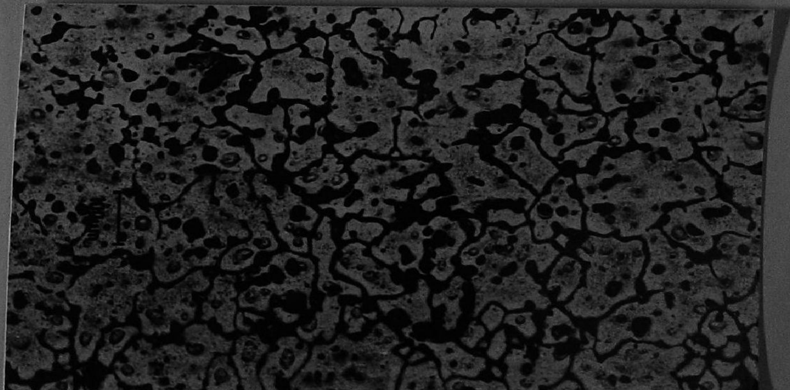

Fig. 10 Microstructure of the idol No. 1761/94

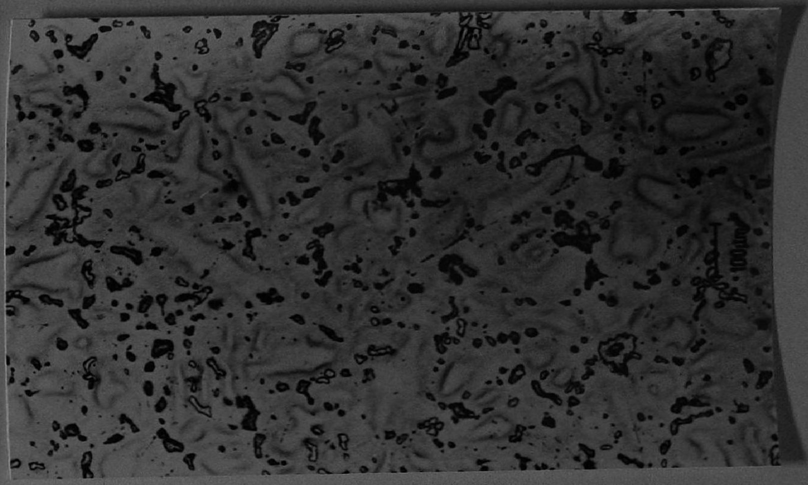

Fig. 11 Microstructure of the idol No. 1782/94

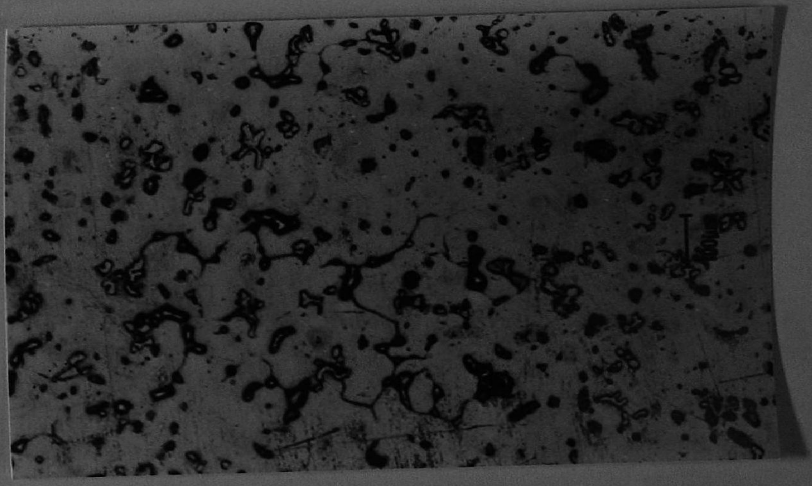

Fig. 12 Microstructure of the idol No. 1885/96

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X-RAY FLUORESCENCE ANALYSIS OF ANCIENT SOUTH INDIAN PANCHALOHA ICONS

Indira Gandhi Centre for Atomic Research, Kalpakkam
Government Museum, Chennai

X-RAY FLUORESCENCE ANALYSIS OF ANCIENT SOUTH INDIAN PANCHALOHA ICONS

INTRODUCTION :

Study of chemical composition (signature) of the icon forms an important aspect in characterising (fingerprinting) the icon. Conventional chemical analysis needs some quantity of the material to be removed from the icon. Therefore we have to use specific methods where the icons and the patina which is formed on their surface as a natural and slow process over many years are not disturbed. X-ray fluorescence analysis is a completely non destructive technique which identifies the elements and gives the concentration of elements present in the sample, irrespective of how those elements are chemically combined. Also the portable XRF system employed in this campaign is an ideal choice for the analysis of icons, which can be carried to the site.

X-RAY FLUORESCENCE TECHNIQUE

X-ray fluorescence (XRF) spectrometry is a method of qualitative / quantitative analysis for chemical elements based on measurement of the energy and intensities of their X-ray spectral lines emitted by secondary excitation. The primary X-ray beam irradiates the specimen, exciting each chemical element to fluoresce (that is emit their characteristic X-rays). The energy of each element 's X-rays is unique to the element (basis of qualitative analysis) and the intensity is a measure of the element's concentration in the sample (basis of quantitative analysis). The samples are not altered or damaged by the analysis. So this technique is a completely non destructive technique for chemical analysis.

There are two significant ways in which the primary X-radiation interacts with the matter (1) photoelectric interaction, and (2) Compton and elastic scattering.

A photon from the X-ray source incident on the sample ejects an electron from an inner shell (K or L) of the sample atom. The primary X-ray source can be an X-ray tube or isotope source emitting photons at suitable energy. For an electron to be ejected from an inner shell, the incident X-ray energy must be somewhat greater than the absorption edge for that energy level. The vacancy produced in the inner shell is then filled by an electron from an outer shell (L, M or N) and in this process a fluorescent X-ray photon is emitted whose energy is characteristic of the atomic number of the atom and the electron shells between which the transition occurred. Each type of transition for each electron shell of each type of atom has a specific range of fluorescent X-ray energies. These characteristic lines can be analysed using wave length dispersive technique or energy dispersive technique, for elemental analysis. Here we have used energy dispersive technique for the current investigation.

The second interaction causes the incident photons to scatter back from the sample and is genarally referred to as backscatter. This can result in loss of energy due to Compton reaction or elastic scattering . These interactions are always present and occur with a probability that is largely dependent on the overall matrix composition. While interpreting the

XRF spectrum, presence of the back scattering and the Compton peaks should be taken into account, for possible interference with characteristic lines of other elements .

INSTRUMENT USED

Asoma 200/400 isotope based portable XRF system has been used for this study. This instrument has a remote measuring head attached to the console. There are two isotope sources Curium-244 (^{244}Cm - 30 mci), and Americium-241 (^{241}Am -20 mci) for primary excitation of the sample. The X-radiation fluoresced and scattered from the sample is detected by a high resolution, gas-filled proportional counter. Each photon absorbed by proportional counter gives rise to a pulse, whose height is proportional to the energy of the photon. These pulses are sent to a multi channel analyser (4096 channels) . The data is acquired by a PC for further analysis.

EXPERIMENTAL DETAILS:

The icons are having complex shapes with varying contours and flatness. Sharp changes in contours will effect the efficiency of data collection. Therefore relatively flat surfaces of the icons were chosen for the analysis. The different regions chosen are like crown, face, belly, back, hand, leg etc. The XRF probe was oriented so as to have maximum contact area on the surface of the icon.

Both (^{241}Am and ^{244}Cm) were used for excitation, as each of the source is sensitive in exciting a different set of elements Americium source is used to analyse Sn,Pb,Sb,Bi and Ag. Curium source is used to analyse Cu, Zn, Fe, Ni, Au, As and Co. Two separate spectra are recorded for analysis. An exposure time of 160 sec has been chosen for this study so that signal to noise ratio is good . And no new elements are detected by increasing the exposure time any further

Energy Calibration :

The data essentially consists of count vs channel number. The channel number has a linear relationship with the photon energy. The channels are calibrated by acquiring spectra from two known pure elements namely, Cu (8.04 Kev) and Ag (22. Kev).

Background Correction :

The contribution to the background is mainly from the matrix. We assume that the predominant component in the matrix is Cu. Therefore we have obtained the back ground count (I_B) for the line corresponding to each element for back ground correction. The corrected count of a spectral line of an element (X) therefore is,

$$I(X) = I_0(X) - I_B(X) \qquad (1)$$

where I_0 (X) is the count corresponding to an element X before back ground correction.

The collection efficiency (response) of the probe also depends on the curvature of the surface to be analysed. Therefore eq.(1) is modified as

$$I(X) = I_0(X) - I_B(X) * I_{icon}(Cu) / I_{ref}(Cu) \qquad \text{———(2)}$$

where $I_{icon}(Cu)$ is the count of the spectral line corresponding to copper in the icon being analysed and $I_{ref}(Cu)$ is the count of the spectral line corresponding to copper in the pure copper block.

Clearly, back ground correction is not applied to Cu (except in special cases where correction is applied with respect to adjacent major peak)

Quantitative Analysis:

As calibration standards are not available for *Panchaloha*, quantitative analysis has been done by considering the relative percentage of each element with respect to the total count of the elements (K_α of Cu, K_α of Pb, K_α of Fe, K_α of Sn) present. The elements and the corresponding spectra considered are listed in tables 1 to 18 Relative efficiencies for these spectral lines have been assumed to be same for this analysis

EFFECT OF PATINA

Most of the icons are covered with patina on the surface. The thickness of the patina is of the order of 100 to 300 μm. The penetration of X-rays is confined only to 50-100 μm. Thus there is every possibility of X-rays seeing only the patina but not the actual metal surface. To study the effect of patina on the XRF analysis, on 3 of the icons , the region of analysis is polished to remove the patina and expose the metal of the body of the icon. XRF analysis was done before and after removing the patina. Fig.1 shows the typical XRF spectra from a surface obtained before and after removal of patina Tables 1.1 to1.3 give the composition of elements obtained before and after removal of patina

It was observed that the removal of the patina has an increase in the overall counts. It can be seen that no new element is observed in the XRF spectrum after polishing In general the copper content is more in the metal of the icon compared with that in the patina Cu content analysis made on the patina is underestimated in the range 1.3% to 12.4%. The other elements particularly Pb and Sn are overestimated in the patina. Overestimation is to the tune of 13.8% to 61.3% for Pb and 20 3% to 40 07% for Sn Fe has shown significant variation only in one case.

This variation in the elemental composition in the patina compared with that in the icon is due to differential leaching of the elements. This leaching is from the metal to adherent soil and from adherent soil to the surroundings when the icon is buried.
The variation in patina on metal composition is a very significant and unique fingerprint of great value as it can not be duplicated by any proven scientific methodology. Its value is similar to unique defects in icon casting and both these fingerprints are completely independent of each other.

RESULTS

Eighteen icons belonging to Chola period were analysed . Fig. 2 to Fig. 5 show typical XRF spectra obtained. In order to preserve the antiquity of the icon XRF analysis is confined to the surface only Interpretations are based on these results only. An error bar as indicated in the section on effect of patina has to be taken into account while extrapolating the results.

(1) The major constituent in all these icons is copper. The additive elements Sn, Pb, and Fe were present in all the 18 icons, with varying compositions. This indicates the variation in the metallurgical practices prevalent in the Chola period.

(2) Change of composition from icon to icon : Cu composition is varying from 68% to 97%, Sn from 1.72% to 12.79%, Pb from 1.20% to 18.35% and Fe from nil% to 5.26% (except in one specific case Out of the 18 icons analysed

(3) Change of composition was observed from region to region within the same icon. This variation was within about 10% in general.

In a few cases large deviation was observed in some regions (ex : idol no. 1526/89 seat region, and 1886/96 pedestal region). This may be due to one or more of the following reasons .

1. localised differential leaching when the icon was buried,
2. employing a different melt for that portion of the icon at the time of casting,
3. differential segregation of alloying elements during solidification of cast icon.

(4) In general the patina appeared whitish where lead content is observed to be high. The patina is greenish where the tin content is high.

(5) In one of the icons, in the pedestal region, Fe was the major element unlike in other places. This is adjacent to a tie-hole. The tie-holes are used to tie the icon to a platform during festival processions. It is likely that the icon was buried along with the iron support rod in the tie hole. In due course the iron rod might have disintegrated and enriched the adherent soil with Fe. An alternative possibility is that this may be due to a subsequent repair where Fe rich alloy might have been used. True picture can come out only if the metal core beneath the surface is analysed. Fig.6-7 show the XRF spectrum of this region.

(6) The asymmetry in the K_α peak of Cu has indicated the presence of Zn. But K_α of Zn could not be resolved from K_α of Cu peak in the present configuration due to non availability of suitable filters.

(7) Gold and silver could not be detected . This may be due to their absence in the patina. Due to their noble nature, Au and Ag may not have participated in environmental interactions.

FINGERPRINTING OF SOUTH INDIAN PANCHALOHA IDOLS

XRF Analysis:

1. Idol No. 1341/86

S. No	Spectrum No	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1341-c1	Crown	**84.24**	**3.16**	**6.10**	6.49	
2.	1341-cbp	Crown back projection	**74.22**	**4.72**	**9.41**	**11.64**	
3.	1341-lh1	Left hand	83.65	3.41	6.73	6.19	
4.	1341-rh1	Right hand	82.36	3.93	8.04	**5.65**	
5.	1341-s1	Seat	83.23	3.55	6.85	6.35	
6.	1341-pf1	Pedestal Front	78.20	4.25	8.72	8.80	

Average	Body	81.54	3 75	7.43	7.26	
	Pedastal	78.20	4 25	8.72	8.80	
	Whole idol	80.98	3.84	7.64	7.52	

2. Idol No. 1761/94

S. No	Spectrum No	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1	1761-c5	Crown	89.92	**4.49**	2.65	2 92	
2	1761-lh2	Left hand	89 05	3.98	3.65	3.31	
3.	1761-rh1	Right hand	90 65	3 11	2.98	3.24	
4.	1761-b5	Belly	91.00	**3.08**	**2.31**	3.58	
5	1761-s2	Seat	**91.50**	3.13	2 60	**2.75**	
6.	1761-pb5	Pedastal back	89.67	-	**4.17**	6.14	
7.	1761-dc4	pedestal down corner	89.33	3.18	2.82	4.65	
8.	1761-pf6	Pedastal front	**85.42**	3.43	3.99	**7.15**	

Average	Body	90.42	3.56	2.83	3.16	
	Pedastal	88.14	2.20	3.66	5 98	
	Whole idol	89.56	3.05	3.15	4.22	

3. Idol No. 1526/89

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1526-cp5	Crown projection	90 43	2.78	4.70	2.07	Patina white in colour on the icon
2	1526-s5	Seat	70.61	3.96	22.89	2.52	
3.	1526-pf5	Pedastal Front	85.40	4.00	6.24	4.34	
Average		Body	80.52	3.37	13.80	2.30	
		Pedastal	85 40	4.00	6.24	4.34	
		Whole idol	82.15	3.58	11.28	2.98	

4. Idol No. 330

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1	330-c5	Crown	74.11	3.70	8.4	13.78	Greenish Patina in isolated locations on the icon
2.	330-ck5	Cheek	74.87	3.12	7.32	14.67	
3.	330-pf7	Pedastal front-corner	**80.97**	**2.89**	**6.20**	**9.93**	
4.	330-pf5	Pedastal front-centre	**20.91**	**41.44**	**13.97**	**23.66**	See RESULTS
Average		Body	74 49	3 41	7 86	14 23	
		Pedastal	80.97	2.89	6.20	9.93	330-pf5 not considered
		Whole idol	76 65	3 23	7.30	12.79	

5. Idol No. 9/27-28

S. No	Spectrum No	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	9-27-28b	Belly	**88.37**	2.83	**7.02**	**1.76**	
2.	9-27-28s	Seat	78.94	**1.96**	**14.86**	4.22	
3.	9-27-28p	Pedastal	**74.23**	**6.43**	13.58	**5.74**	
Average		Body	83.66	2.40	10.94	2.99	
		Pedastal	**74.23**	6.43	13 58	5.74	
		Whole idol	80.51	3.74	11.82	3.91	

6. Idol No. 1742/96

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1742-cp1	Crown Projection	79.23	3.7	11.34	5.71	Greenish patina through out the
2.	1742-p1	Pedastal	82.35	5.14	8.68	3.81	icon

Average	Body	79.23	3.7	11.34	5.71	
	Pedastal	82.35	5.14	8.68	3.81	
	Whole idol	80.79	4.42	10.01	4.76	

7. Idol No. 1709/90

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1709-c5	Crown	97.38	-	1.21	1.39	
2.	1709-pf5	Pedastal front	96.76	-	1.18	2.04	

Average	Body	97.38	-	1.21	1.39	
	Pedastal	96.76	-	1.18	2.04	
	Whole idol	97.07	-	1.20	1.72	

8. Idol No. 161

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	161-b5	Belly	89.01	2.58	2.17	6.22	
2.	161-p5	Pedastal	92.12	2.25	1.35	4.27	

Average	Body	89.01	2.58	2.17	6.22	
	Pedastal	92.12	2.25	1.35	4.27	
	Whole idol	90.57	2.42	1.76	5.25	

9. Idol No. 1885/96

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1885-c5	Crown	77.25	4.95	7.83	9.95	Greenish patina in a few locations
2.	1885-pf5	Pedastal Front	84.82	2.02	5.70	7.44	on the icon

Average	Body	77.25	4.95	7.83	9.95	
	Pedastal	84.82	2.02	5.70	7.44	
	Whole idol	81.04	3.49	6.77	8.70	

10. Idol No. 1887/96

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1887-c1	Crown	71.54	**3.66**	**13.45**	11.33	Greenish patina in isolated locations on icon
2	1887-s1	Seat	72.98	4.00	9.77	13.24	maximum
3.	1887-pf1	Pedastal Front	**86.35**	-	**3.96**	**9.68**	on the
4.	1887-pb5	Pedastal back	**66.76**	4.23	12.95	**16.04**	pedastal
5.	1887-dc1	Pedastal region down corner	70.95	**8.21**	9.18	11.64	

Average	Body	72.26	3 83	11.61	12.29	
	Pedastal	74.68	4.14	8.69	12.45	
	Whole idol	73.71	4.02	9.86	12.38	

11. Idol No. fp

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	fp-b5	Belly	**85.73**	-	**9.39**	**4.86**	white patina
2.	fp-pf5	Pedastal front	**66.42**	**4.51**	**24.11**	4.94	through out the
3.	fp-dc2	Pedastal down corner	66.88	**6.29**	21.54	**5.28**	icon

Average	Body	85.73	-	9.39	4.86	
	Pedastal	66.65	5.4	22.83	5.11	
	Whole Idol	73.01	3.6	18.35	5.03	

12. Idol No. 78-9/43

S No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	78-9-43c	Crown	98.12	-	0.87	0.99	no patina
2.	78-9-43p	Pedastal	91.79	-	3.19	5.00	visible

Average	Body	98.12	-	0.87	0.99	
	Pedastal	91.79	-	3.19	5.00	
	Whole idol	94.96	-	2.03	2.99	

13. Idol No. 659/70

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	659-70cp	Crown projection	72.02	5.76	7.87	14.33	Greenish patina through out
2.	659-70pb	Pedastal back	79.68	4.83	5.00	10.47	the icon

Average	Body	72.02	5.76	7.87	14.33	
	Pedastal	79.68	4.83	5.00	10.47	
	Whole idol	75.85	5.26	6.43	12.40	

14. Idol No. 1783/94

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1783-ch5	Cheek	**80.97**	3.88	**6.04**	9.10	patina white and greenish in colors
2.	1783-s5	Seat	80.24	**3.02**	7.20	**9.52**	on the icon
3.	1783-pd5	Pedastal down	**71.38**	**8.00**	**11.63**	**8.97**	

Average	Body	80.61	3.45	6.62	9.31	
	Pedastal	71.38	8.00	11.63	8.97	
	Whole idol	77.53	4.97	8.29	9.20	

15. Idol No. 1153/83

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1153-ct5	Chest	85.53	2.00	6.70	5.76	
2.	1153-p5	Pedastal	58.48	4.48	19.95	17.07	white and greenish patina in this region

Average	Body	85.53	2.00	6.70	5.76	
	Pedastal	58.48	4.48	19.95	17.07	
	Whole idol	72 01	3.24	13.33	11.42	

16. Idol No. 570/66

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	570-66c1	Cheek	**93.84**	1.40	**1.499**	3.24	Reddish brown
2.	570-66s1	Seat	**94.77**	-	**1.76**	**3.45**	patina on
3.	570-66p1	Pedastal	94.16	1.16	1.52	**3.15**	the icon

Average	Body	94.31	0.7	1.63	3.35	
	Pedastal	94.16	1.16	1.52	3.15	
	Whole idol	94.26	0.85	1.59	3.28	

17. Idol No. 1886/96

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	1886-c5	Cheek	**77.39**	**3.80**	9.18	9.61	Greenish
2.	1886-pf5	Pedastal front	62.07	5.46	20.29	12.16	patina
3.	1886-pb5	Pedastal back	**57.12**	3.87	**26.64**	**12.35**	on the
4.	1886-dc2	pedestal down corner	75.99	**6.08**	**9.09**	**8.82**	icon

Average	Body	77.39	3.80	9.18	9.61	
	Pedastal	65.06	5.14	18.67	11.11	
	Idol	68.14	4.80	16.3	10.74	

18. Idol No. 563/66

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1.	563-s1	Seat	95.04	-	1.99	2.96	
2.	563-pf1	Pedastal front	94.25	-	2.57	3.16	

Average	Body	95.04	-	1.99	2.96	
	Pedastal	94.25	-	2.57	3.16	
	Whole idol	94.65	-	2.28	3.06	

Table 1.1 **Idol No. 1887/96**

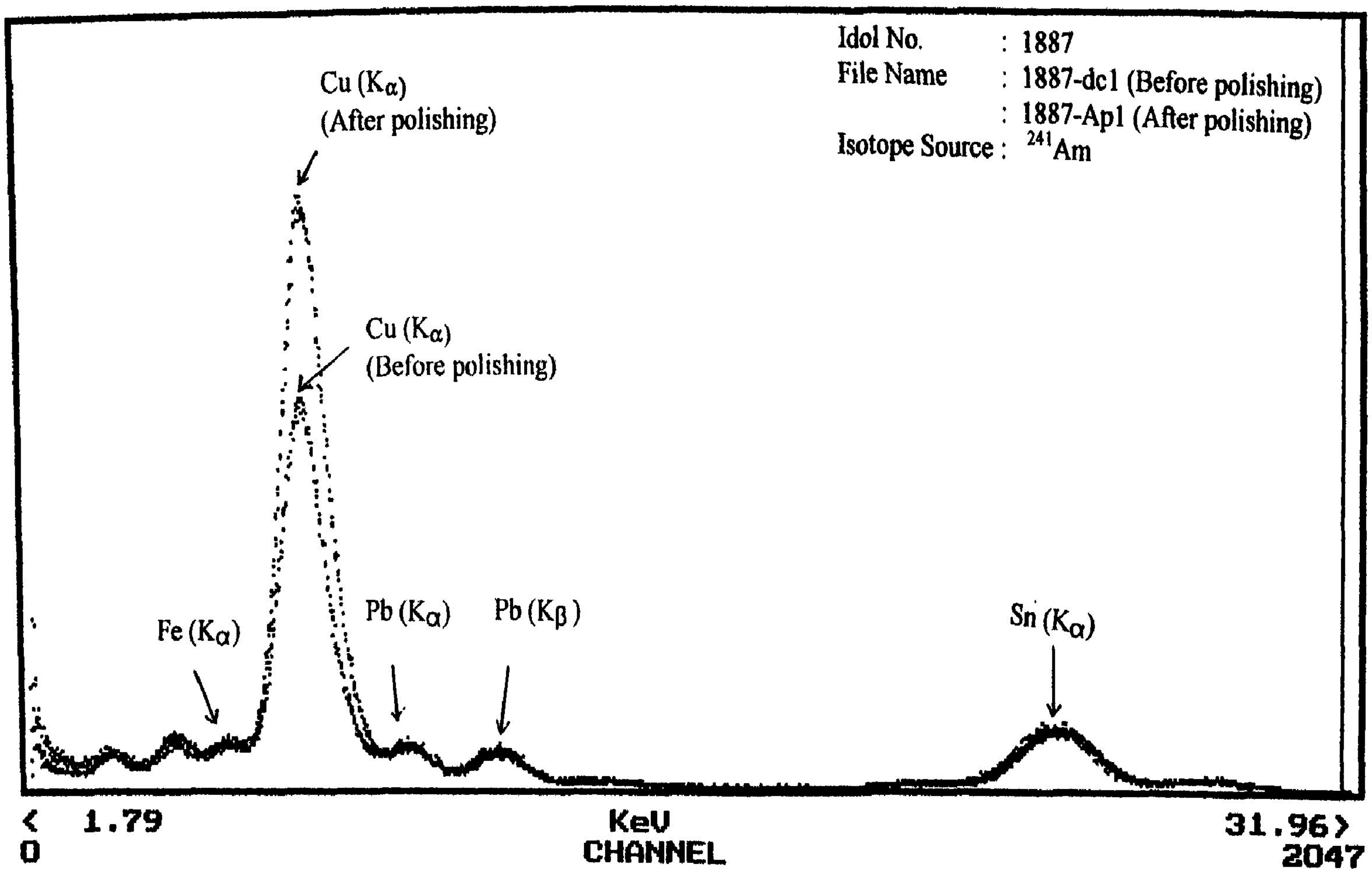
S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1	1887- apl	Pedastal region after polishing	81.07	4.84	5.69	8.31	without patina
2	1887-dcl	Pedastal region before polishing	70.95	8.21	9.18	11.64	with patina
Percentage Difference with patina			-12.4	+69.6	+61.33	+40.07	

Table 1.2 **Idol No. 1886/96**

S. No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
1	1886-ap2	Down corner after polishing	78.51	6.12	7.97	7.37	without patina
2	1886-dc2	Down corner before polishing	75.99	6.08	9.09	8.82	with patina
Percentage Difference with patina			-3.3	-0.6	+13.8	+20.3	

Table 1.3 **Idol No. 1761/94**

S No	Spectrum No.	Region	Cu(%)	Fe(%)	Pb(%)	Sn(%)	Remarks
2.	1761-ap2	Down corner after polishing	90.51	3.28	2.44	3.75	without patina
1.	1761-dc4	pedestal down corner before polishing	89.33	3.18	2.82	4.65	with patina
Percentage Difference with patina			-1.3	-3.0	+16.3	+24	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(After polishing)
Cu (Kα)
(Before polishing)
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Fig.1

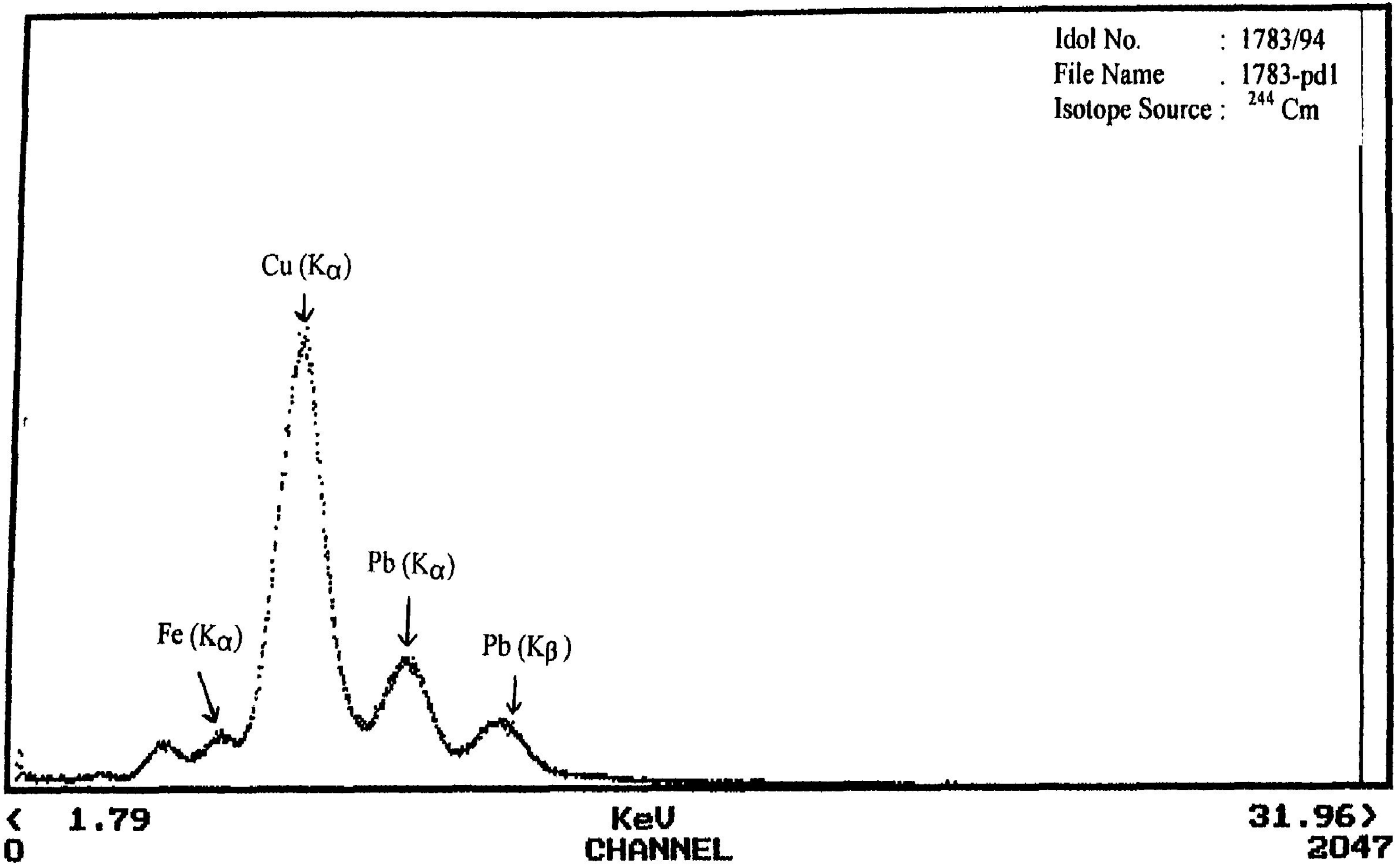
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Fig.2

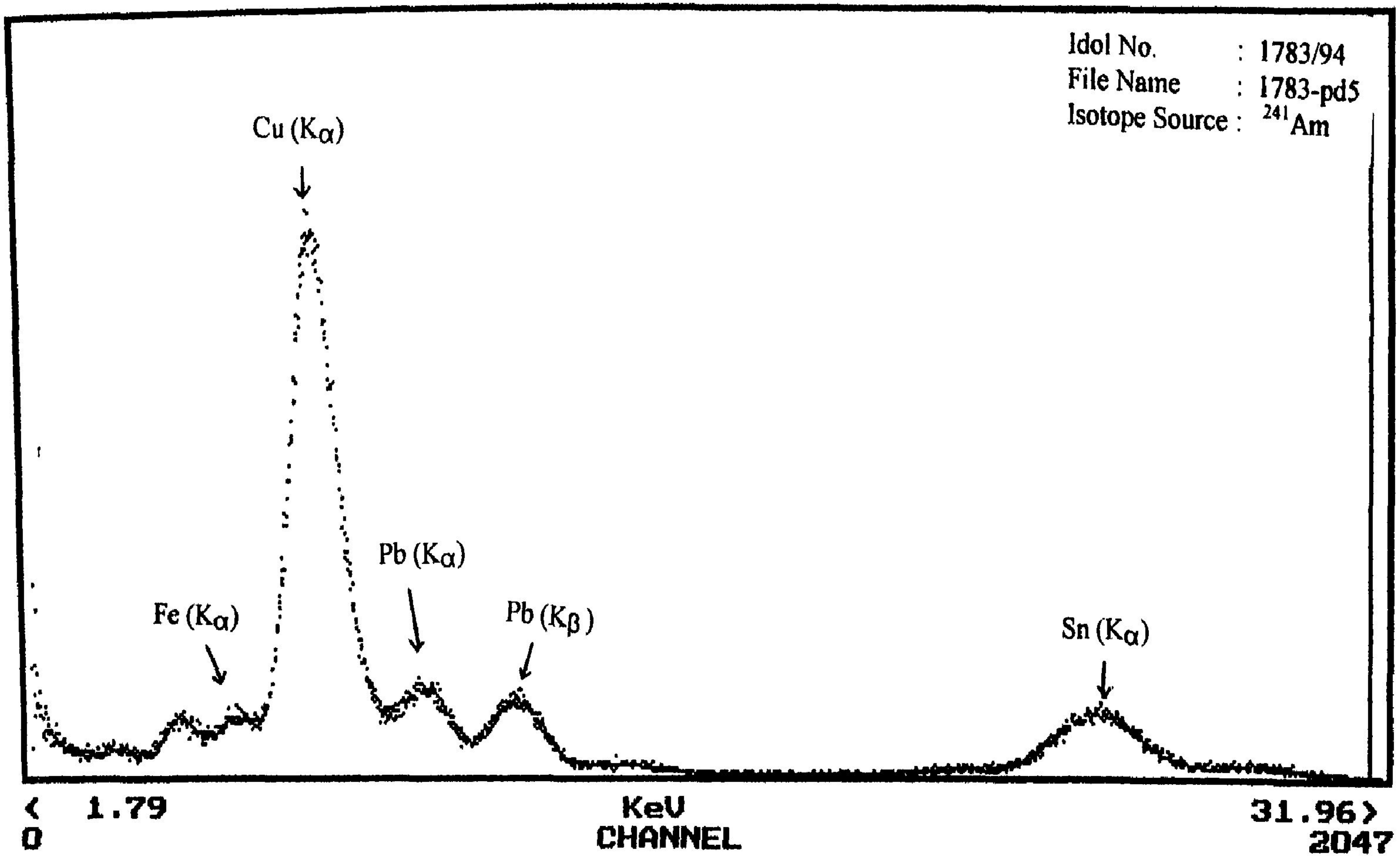
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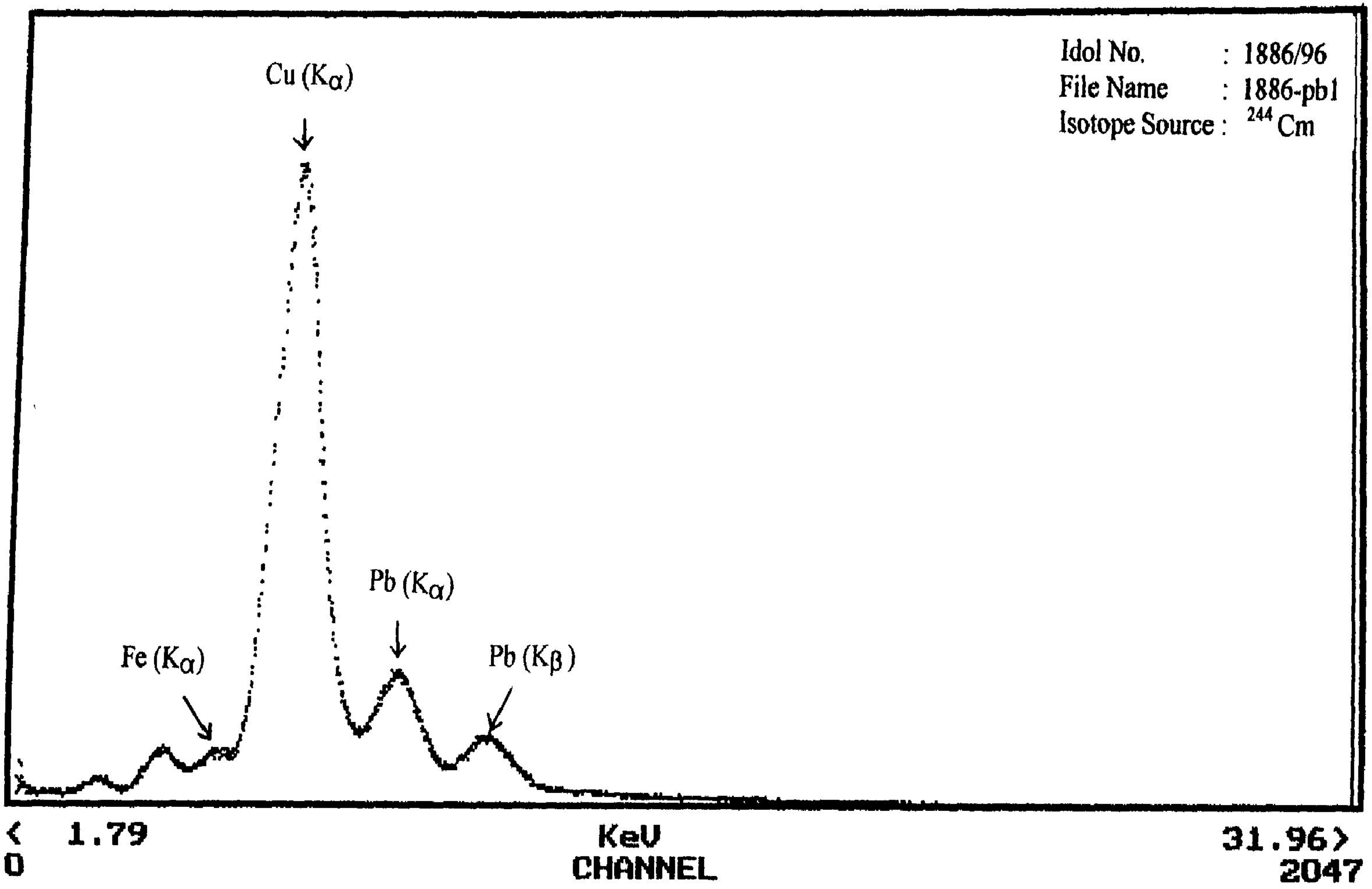
Fig.3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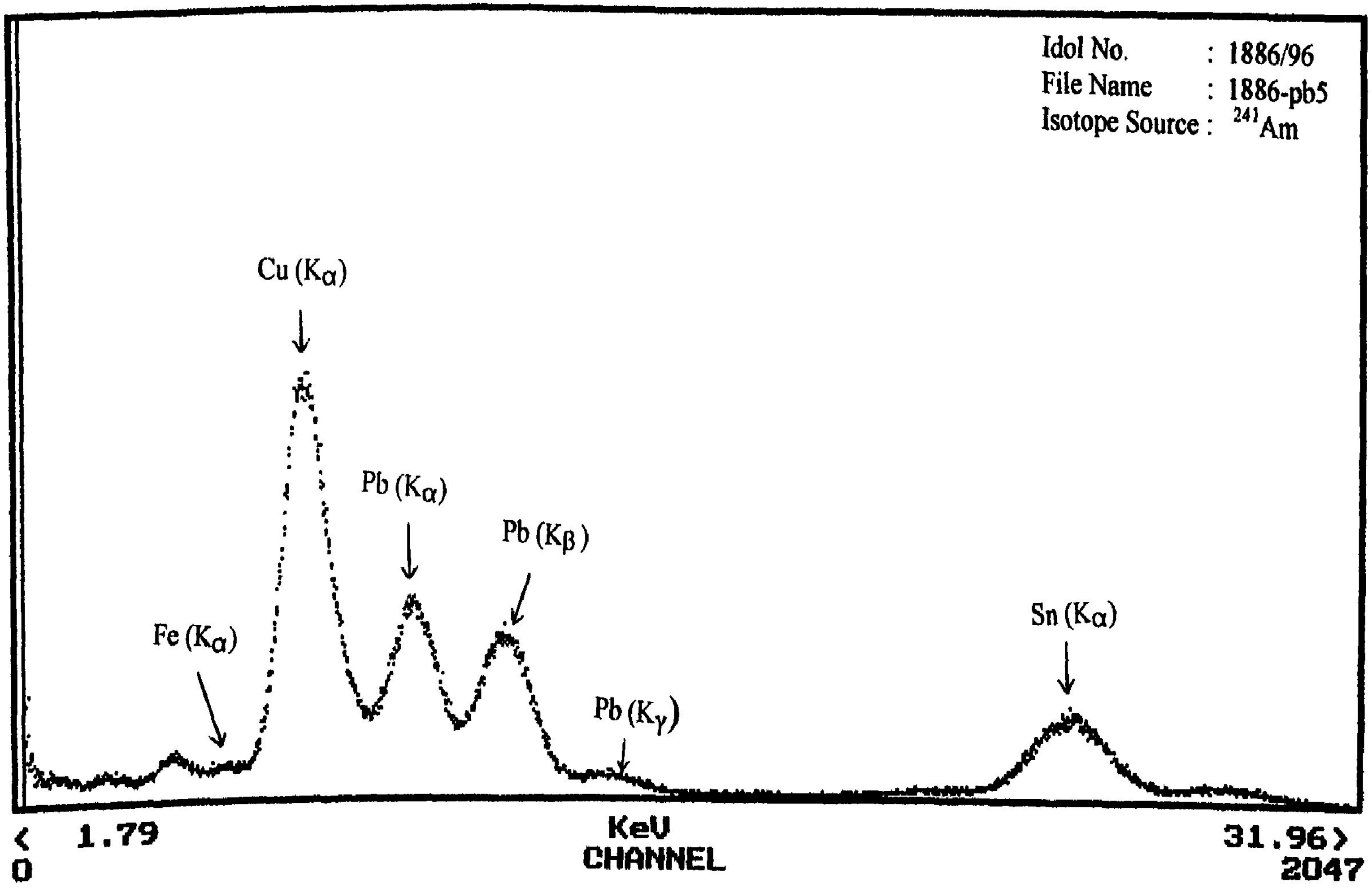
CHANNEL
31.96 >
2047

Fig.4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2047

Fig.5

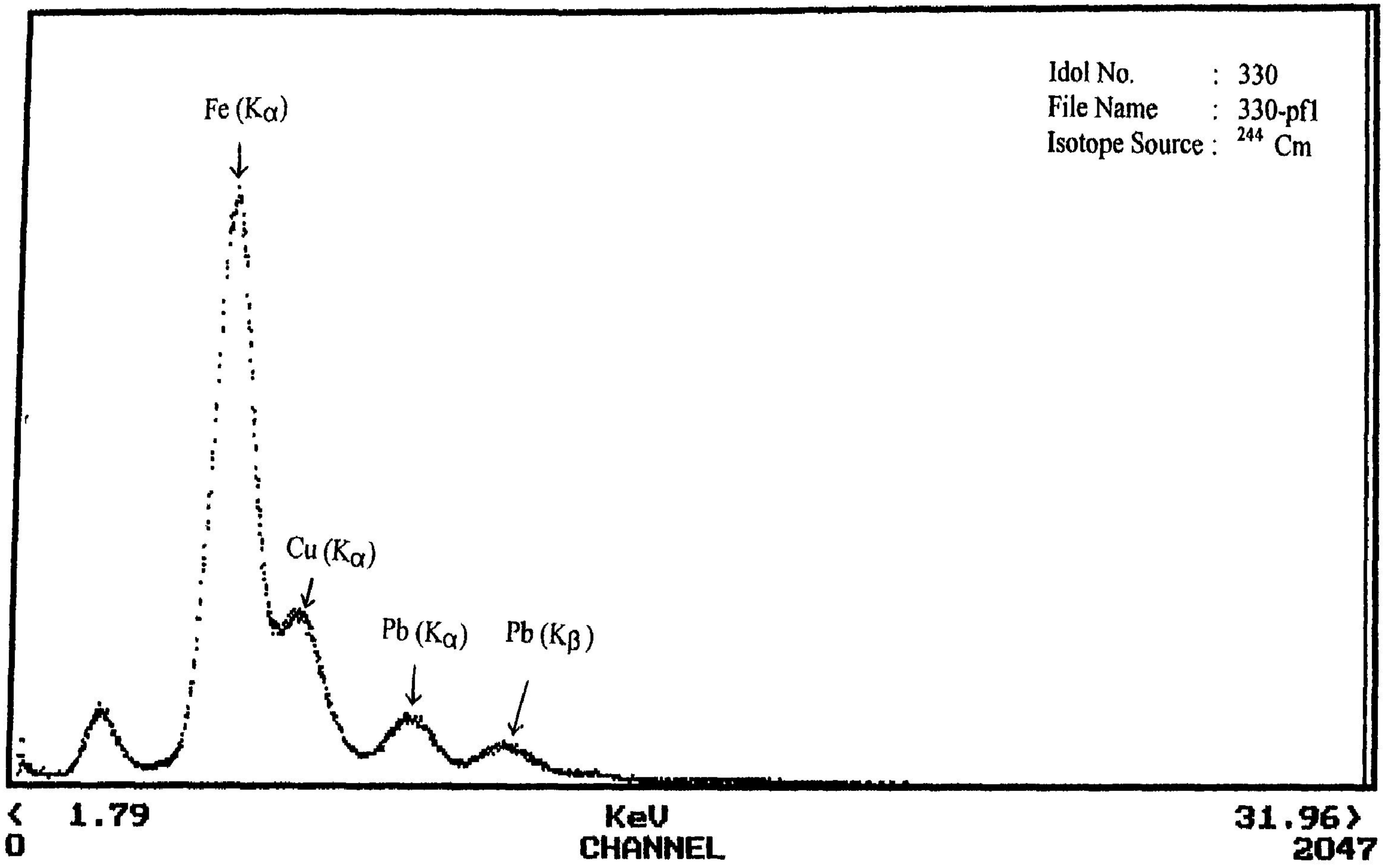
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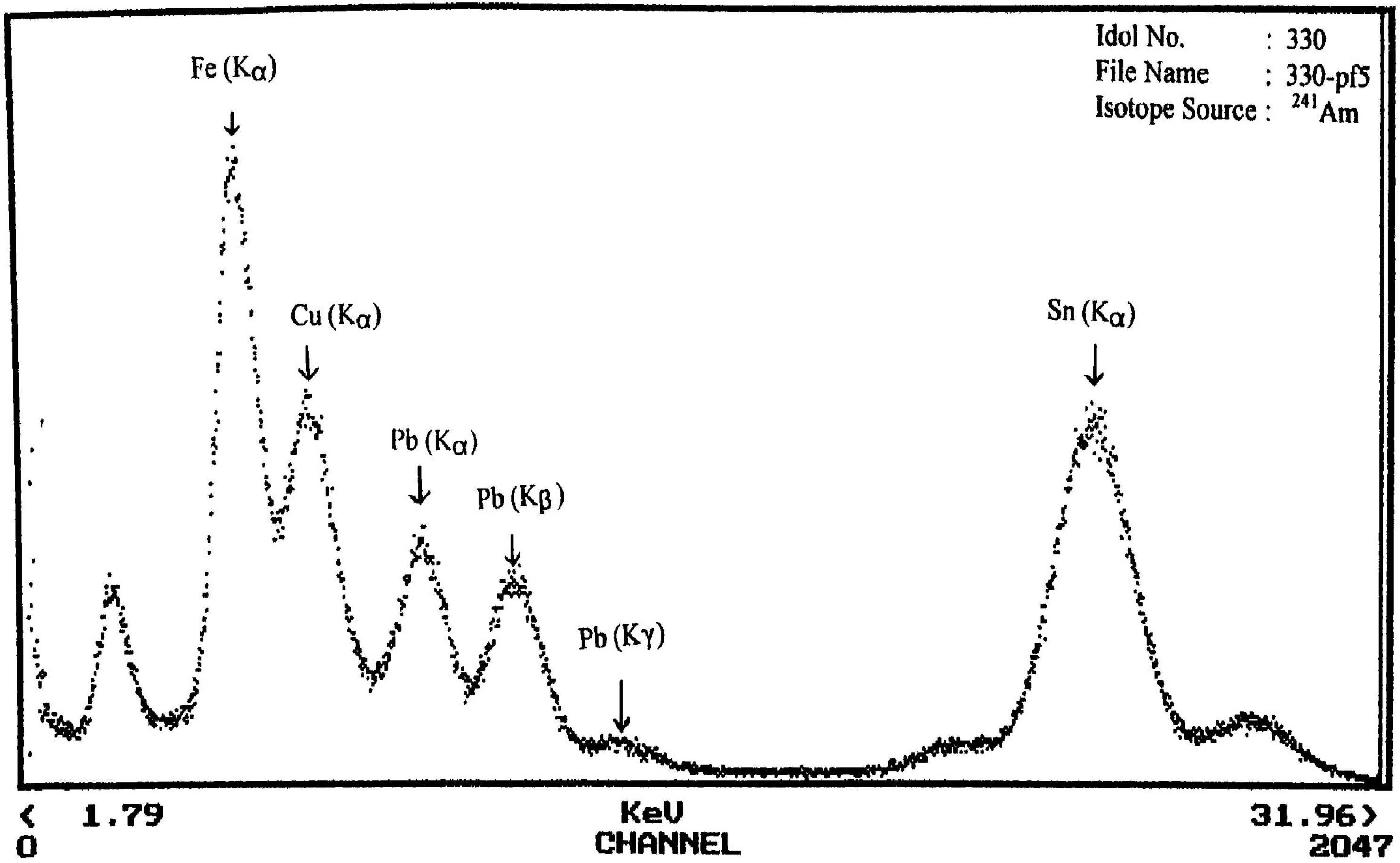
Fig.6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31.96>
2047

Fig.7